

WHAT IS CLAIMED IS:

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1. A method for fabricating a capacitor of a
semiconductor device, comprising the steps of:
5 forming a lower electrode on a semiconductor
substrate;
forming a dielectric layer on the lower electrode by
forming a first amorphous TaON thin film on the
lower electrode;
10 annealing the first amorphous TaON thin film in
an NH₃ atmosphere;
forming a second amorphous TaON thin film on the
lower electrode; and
annealing the second amorphous TaON thin film to
15 form a multilayer TaON dielectric film; and
forming an upper electrode over the TaON dielectric
film.

20 2. The method according to claim 1, wherein forming
the Lower electrode further comprises forming a structure
selected from a group consisting of
25 1) a single conductive layer, the single conductive
layer being formed from a material selected from a group
consisting of doped polysilicon and metal, and

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2) a plurality of conductive layers, the plurality of conductive layers comprising at least two layers formed from one or more materials selected from a group consisting of doped polysilicon and metal; and

5 further wherein forming the upper electrode further comprises forming a structure selected from a group consisting of

10 1) a single conductive layer, the single conductive layer being formed from a material selected from a group consisting of doped polysilicon and metal, and

15 2) a plurality of conductive layers, the plurality of conductive layers comprising at least two layers formed from one or more materials selected from a group consisting of doped polysilicon and metal.

3. The method according to claim 2, wherein the metal may be selected from the group consisting of TiN, Ti, TaN, W, WN, WSi, Ru, RuO₂, Ir, and Pt.

20 4. The method according to claim 1, wherein forming the lower electrode further comprises forming a layer of doped polysilicon, the surface of the doped polysilicon being characterized by a hemispherical grain structure.

5. The method according to claim 1, wherein forming the lower electrode comprises forming a layer of polysilicon and further comprises removing a natural oxide film on the surface of the lower electrode before forming the first 5 amorphous TaON thin film,

the natural oxide film being removed by an in-situ dry cleaning process, the dry cleaning process utilizing HF, SiF₆, or NF₆,

or an ex-situ wet cleaning process, the wet 10 cleaning process utilizing an HF solution.

6. The method according to claim 5, wherein removing the natural oxide film further comprises cleaning the lower electrode with a NH₄OH solution, H₂SO₄ solution, or a 15 combination thereof.

7. The method according to claim 1, wherein forming the first amorphous TaON thin film further comprises depositing a first TaON thin film in a LPCVD chamber 20 maintained at a temperature of not more than about 600°C; and

further wherein forming the second amorphous TaON thin film further comprises depositing a second TaON thin film in

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a LPCVD chamber maintained at a temperature of not more than about 600°C.

8. The method according to claim 7, wherein depositing
5 the amorphous TaON thin films further comprises
evaporating $Ta(OC_2H_5)_5$ in an evaporator maintained at a temperature of 150 to 200°C to obtain a Ta-containing chemical vapor;
10 transporting the Ta-containing chemical vapor through a supply tube, the supply tube being maintained at a temperature of at least 150°C; and
injecting the $Ta(OC_2H_5)_5$ vapor into the LPCVD chamber.

9. The method according to claim 1, wherein forming at least one of the amorphous TaON thin films further comprises
15 supplying a controlled quantity of the Ta-containing chemical vapor to the LPCVD chamber, the quantity being controlled by a mass flow controller;
20 supplying a controlled quantity of a reaction gas to the LPCVD chamber, the reaction gas comprising NH_3 ; and maintaining the LPCVD chamber within a temperature range between 300 and 600°C and at a pressure of less than 10 Torr, to thereby induce a surface reaction between the Ta-containing chemical vapor and the reaction gas.

10. The method according to claim 9, wherein forming at least one of the amorphous TaON thin films further comprises

5 supplying a controlled quantity of O₂ gas to the LPCVD, the quantity ranging from 5 sccm to 500 sccm.

11. The method according to claim 9, wherein forming at least one of the amorphous TaON thin films further comprises

10 spraying the Ta-containing chemical vapor into the LPCVD chamber through a gas distribution head and onto the lower electrode in a direction substantially perpendicular to the lower electrode.

15 12. The method according to claim 9, wherein forming at least one of the amorphous TaON thin films further comprises

20 spraying the Ta-containing chemical vapor into the LPCVD chamber through an injector configured and arranged to establish a parabolic flow of the Ta-containing chemical vapor through the LPCVD chamber and onto the lower electrode.

13. The method according to claim 12, wherein forming at least one of the amorphous TaON thin films further comprises

5 spraying the Ta-containing chemical vapor into the LPCVD chamber through a first injector; and spraying the reaction gas into the LPCVD chamber through a second injector, the first and second injectors being configured and arranged to establish a counter-current flow of the gas and the vapor through the LPCVD chamber and onto the lower electrode.

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15 14. The method according to claim 1, wherein the annealing steps further comprise a plasma treatment in an NH₃ or N₂O atmosphere.

20 15. The method according to claim 1, wherein the annealing steps further comprise a low-temperature annealing process in a UV-O₃ or O₃ atmosphere.

20 16. The method according to claim 1, wherein the annealing steps further comprise heating the amorphous TaON thin film to a temperature between 650 and 950 °C under an atmosphere of N₂O, O₂, or N₂.

17. The method according to claim 1 wherein forming the lower electrode further comprises nitriding an upper surface of the lower electrode using in-situ plasma under an NH₃ atmosphere for 1 to 5 minutes before forming the first amorphous TaON thin film.

18. The method according to claim 1 wherein forming the lower electrode further comprises treating the surface of the lower electrode with a plasma in an N₂O atmosphere to form a thin, homogeneous, oxide layer before forming the first amorphous TaON thin film.

19. A method for fabricating capacitors for semiconductor devices, comprising the steps of:
15 forming a lower electrode on a semiconductor substrate;
forming a first amorphous TaON thin film over the lower electrode;
annealing the first amorphous TaON thin film in an NH₃ atmosphere;
20 forming a second amorphous TaON thin film;
annealing the second amorphous TaON thin film a first time;

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annealing the second amorphous TaON thin film a second time, thereby forming a TaON dielectric film having a multi-layer structure; and

5 forming an upper electrode over the TaON dielectric film.

20. A method for fabricating capacitors for semiconductor devices, comprising the steps of:

10 forming a lower electrode on a semiconductor substrate;

nitriding an upper surface of the lower electrode in an NH₃ atmosphere;

15 forming a first amorphous TaON thin film over the lower electrode;

annealing the first amorphous TaON thin film in an NH₃ atmosphere;

forming a second amorphous TaON thin film;

20 annealing the second amorphous TaON thin film at least once, thereby forming a TaON dielectric film having a multi-layer structure; and

forming an upper electrode over the TaON dielectric film.